A Comparative Study on Position Fixing with GPS to Ascertain Positional Accuracy*

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Abstract

Various techniques have been employed to determine the relative or absolute positions of locations on the surface of the earth to promote effective land management. Continuous Observation Reference Station (CORS) is one of the latest techniques employed in differential GPS positioning. In order to ascertain the positional accuracy of a newly established CORS equipment located on the campus of the University of Mines and Technology (UMaT), this comparative study was carried out. Selected positions around the campus were surveyed and their coordinates computed using a temporarily occupied base and then a CORS base, and the results were compared with the coordinates obtained from a conventional precise traverse. It was observed that the Eastings coordinates obtained from the temporarily occupied reference station compares favourably with those of the conventional method and the CORS with variations in the second and third decimals. Standard errors of -0.144 m and 0.806 m respectively were obtained for the Northings and elevations respectively between the CORS coordinates and that of the conventional method. It was observed that there is a strong correlation between the coordinates of the control points and the relation between the Eastings, Northings and heights were all linear. It could be concluded that the CORS station, which is under study, could be used with minimal error for planimetric and or cadastral surveying purposes.

1 Introduction

The techniques employed in the determination of positions of points on the surface of the earth have seen tremendous improvements over the decades. These are the traditional methods and the use of Global Positioning System (GPS) techniques. The traditional methods of surveying include triangulation, traversing and leveling which were used extensively before the 1980s prior to the advent of GPS surveying (Anon, 2008). In the conventional methods of surveying inter-visibility is required and calls for clearing to achieve the necessary line-of-sight. GPS surveys, on the other hand, utilise a number of satellites as the space references to compute the coordinates of locations where GPS receivers are mounted, and has the advantage of speed, cost effectiveness, fixes positions accurately with greater flexibility and has accessibility to remote areas. Some techniques are employed to further improve the accuracy of GPS observed positions. Some of these methods include Static GPS surveying, differential GPS, Real Time Kinematics (RTK) and lately the use of CORS. Static surveying involves occupying a point and collecting satellite telemetry for a period (usually 2 hours, time adjusted by distance to reference station). GPS positioning method uses relative positioning techniques where a control in the vicinity is incorporated in the computation of the position to significantly reduce the errors that occur in static or absolute positioning (Torge, 2001). RTK surveying is where GPS signal corrections are transmitted in real time from a reference receiver at a known location to one or more remote rover receivers. CORS is a GPS receiver located permanently at a strategic position with very accurately predetermined coordinates, and equipped with downloading facilities which process the coordinates of the station and makes them accessible to users on the internet (Anon, 2004). CORS with RTK technique offers surveying on the fly, without loss of accuracy, and is supported by base stations with internet Transmission Control Protocol (Anon, 2009).

The National Geodetic Survey (NGS) of Michigan, USA for example collects the data from their CORS GPS receivers and makes the data available to GPS surveyors so that they can correct for any errors that are in the GPS signals (Anon, 2004). On-line Positioning service software packages have been provided in some countries for GPS users to enable easier ways of determining positions with respect to the CORS network. The University of Mines and Technology (UMaT), Tarkwa, received a donation of a CORS and its accessories to serve the University community, practicing surveyors and the allied mining industry within 40 km radius.

The UMaT CORS, like others, was mounted with the aim of providing high order GPS reference data that will help establish controls with greater accuracy and flexibility while performing surveying for a variety of applications for example. In the provision of reliable and consistent data for establishing spatial relations, legal boundaries, infrastructure projects, mining related projects, environmental assessment and private enterprise development. The accuracy of the base used in post-processing of any fixed position, to a large extent, affect the correctness of the resulting computed coordinates. To ascertain the accuracy of DGPS surveys tied to a permanent reference station compared to those tied to the CORS is of primary concern more especially to cadastral surveyors where discrepancies in fixed boundary coordinates may degenerate into legal boundary conflicts leading to the possible loss of property and lives.

In this paper, the results of a study that was undertaken to determine the accuracy of GPS positioning using the temporary occupied reference station and the CORS as respective bases are given. The results are compared with those of the conventional method.

2 Study Area

The area of study covers part of the UMaT Campus and the Tarkwa Township. Tarkwa is the capital of the Tarkwa Nsuaem Municipal Assembly, a mining community in the Western Region of Ghana. The town is about 85 km from Takoradi, which is the regional capital, 233 km from Kumasi and about 317 km from Accra (Kesse, 1985). The University campus covers an area of approximately 1.39 km^2 of undulating land and pleasant surroundings, about 2 km south of Tarkwa. Already established survey controls stations used in the study area are shown in Fig. 1.

3 Materials and Methods

The materials and methods employed in this research are discussed in the following sections.

3.1 Materials

Control stations for the research were identified and primary data collected by field survey using GPS receivers. Data obtained was processed using spectrum GPS software and analysed with Microsoft Excel.

3.1.1 Equipment

The field equipment includes four single frequency GPS receivers, one CORS and accessories. Also a total station and two reflector targets were used to determine the coordinates of the selected points using classical surveying techniques.

3.1.2 Software

The Spectrum GPS software Version 3.3 was used for the post-processing of the GPS data, while Microsoft Excel and ArcGIS 9.2 were used for the regression analysis and the plotting of the points respectively.
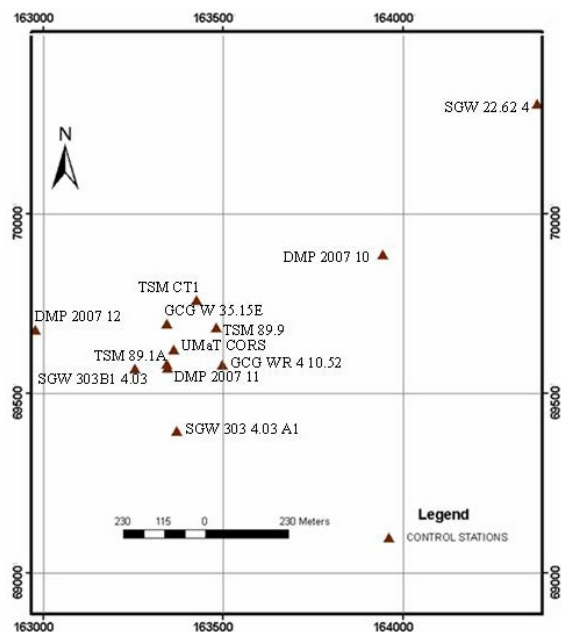

Fig. 1 Sample Location of Control Stations

3.2 Methods

A DGPS survey was conducted with the CORS and a temporary occupied station used as respective bases. A conventional survey was also conducted.

3.2.1 Sampling

A reconnaissance survey was conducted during which the site used for the work was selected. The conditions of the instruments used were also ascertained by checking the battery strength. The receivers were also used to pick at random points and the information downloaded and processed to see if the receivers were functioning properly by comparing the coordinates obtained with the actual coordinates of those points. The discrepancies were found to be minimal and therefore the receivers were considered to be in a good working condition. Also a point of departure test was conducted as a check on the stability of the base control point used, and was found to be good. Eleven controls were selected for the survey such that there was clear view of the sky (see Fig. 1).

3.2.2 Using the CORS

In control point positioning, the coordinates of the antenna position at an unknown point were found with respect to the WGS84 reference frame (local reference frame). In this method, the reference position is occupied and the unknown position is in turn occupied, with the known positions of the satellites, the position of the unknown is computed using a similar method to that of resection. The static technique was used and the rover positions were obtained by the 'leap frog' method while the CORS was operational. The rover receivers were set up on the points whose coordinates were required. The rover was switched off when a link between the rover and the base station was created. The occupation time was between 20 and 40 minutes since the distance between the base and the rover stations was less than 2 km. The time the rover was switched off was recorded. This procedure was repeated until all the controls were occupied. In processing, the downloaded coordinates of the CORS were also used as a base in post-processing of the coordinates of the unknown control points.

3.2.3 Using the Temporary Occupied Reference Station

With the temporary occupied reference station technique, a GPS receiver is mounted on a control point whose coordinates are known and serves as the reference station of the survey. That receiver is referred to as the base receiver of the survey which had the description SG W 22/64 4 and remains until the entire survey is completed. The rest of the receivers (which are referred to as the roving receivers), are moved around the points whose coordinates are required. The time the receiver was switched on; the receiver's serial number and the name of the occupied pillar were recorded in the field book. The roving receivers were also set up on the points whose coordinates were required. The rover was switched off and the time was recorded when a link between the rover and the base station was created. The occupation time was between 30 and 40 minutes. This procedure was repeated until all the controls were occupied. The base receiver was switched off and the time recorded. In processing the data to obtain the coordinates of the points, the coordinates of the reference station were used to compute the differential which in turn was used to adjust the GPS coordinates of the new points.

3.2.4 Using the Classical Survey Method

To enable effective comparison of the two techniques, a classical survey method was carried out to determine the coordinates of the selected controls. A close link traverse was conducted over the sampled controls using a total station; an observation was also made to the mast of the CORS. The closing error between the starting and the closing coordinates by manual computation averaged 0.003 m.

4 Results

Results obtained from processing the data using both the temporary occupied reference station and the CORS as a base were computed. These were compared with the coordinates of the points determined by running a precise traverse over the controls. Tables 1 and 2 show the coordinates that were obtained and their respective discrepancies from the Conventional method's coordinates.

The first row of Table 1 shows that sample station TSM CT1 has GPS post-process average coordinates of 163427.194 m in the eastings, 69760.065 m in the northings and 81.719 m in elevation with respect to the CORS; 163427.178 m, 69760.245 m and 80.846 m in the eastings, northings and elevation respectively with respect to the temporary occupied reference station; and 163427.176 m, 69760.217 m and 80.834 m in the eastings, northings and elevation respectively by the traditional method. This gives differences of 0.038 m in the eastings, -0.144 m in the northings and 0.806 m in the elevation between the CORS coordinates and those of the temporary occupied reference station coordinates. Also there were discrepancies of 0.058 m, 0.060 m and 0.076 m in the eastings, northings and elevation respectively between the coordinates of the temporary occupied reference station and those of the traditional method. In addition, there were differences of 0.038 m, -0.110 m and 0.878 m in the eastings, northings and elevation respectively between the CORS coordinates and those of the Conventional method coordinates (Table 2).

4.1 Analysis of Results

Linear regression analysis was applied to the scatter diagrams of the coordinates to assess the relationships between the coordinates of the Conventional method, the temporary occupied reference station coordinates, and the CORS coordinates. Figs. 2 to 4 show the relationships established between the variables (eastings, northings and elevations).

The post-processed coordinates of the eastings, nothings and heights of the coordinates of the Conventional method against those of CORS show a strong correlation with a coefficient of deterministic (R^2) of 1 in the eastings, northings and heights. Figs. 5 to 7 show the eastings, nothings and elevations of the coordinates of the Conventional method plotted against those of the temporary oc-

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cupied reference post-processed coordinates. In the same way, the post-processed coordinates of the eastings, nothings and heights of the coordinates of the Conventional method against those of temporary occupied reference station have a strong correlation with a coefficient of deterministic (R^2) of 1 in the eastings, northings and heights.

5 Discussion

From the analysis of the results obtained using the three methods, it was observed that variations between the data post-processed using the temporarily occupied reference station and the CORS were very small. Discrepancies in the eastings and northerns coordinates, and elevation were determined with respect to the coordinates of the Conventional method of the same control points (see Table 2).

The coordinates obtained from the CORS, temporarily occupied reference station and the conventional method compare favourably with each other with variations in the second and third decimals. From Table 2 there were, however, small variations of averaging values of 0.038 m, - 0.144 m and 0.806 m for the eastings, nothings and heights respectively for the CORS and temporarily occupied reference station.

Table 1 Coordinates of Sample Points using CORS, Temporary Occupied Referenced Station and by the Conventional Method

Points Description	CORS			Temporary Occupied Reference Station (TOR)			Conventional Method (CM)		
	E m	N m	Z m	E' m	N' m	Z' m	E` m	N`m	Z` m
TSM CT1	163427.194	69760.065	81.719	163427.178	69760.245	80.846	163427.176	69760.217	80.834
SGW 303 4.03 A1	163372.166	69396.262	68.264	163372.201	69396.405	67.415	163372.252	69396.403	67.342
GCG WR 4 10.52	163499.247	69581.511	72.991	163499.239	69581.512	72.26	163499.265	69581.574	72.214
DMP 2007 10	163945.922	69887.706	101.302	163945.906	69887.877	100.587	163945.91	69887.87	100.45
SGW 22.62 4	164374.344	70306.613	79.612	164374.342	70306.777	78.872	164374.342	70306.777	78.872
TSM 89.1A	163344.962	69582.352	75.786	163344.988	69582.513	74.939	163345.017	69582.572	74.846
DMP 2007 12	162979.339	69678.616	99.625	162979.351	69678.764	98.915	162979.338	69678.749	98.733
TSM 89.9	163482.643	69684.168	72.875	163482.946	69684.312	72.055	163482.625	69684.311	71.982
DMP 2007 11	163346.75	69571.345	75.647	163346.762	69571.505	74.788	163346.834	69571.117	74.683
SGW 303B1 4.03	163255.828	69570.311	68.876	163255.824	69570.469	68.048	163255.819	69570.443	67.971
GCG W 35.15E	163343.931	69694.035	74.005	163343.926	69694.194	73.18	163343.811	69694.119	73.147
UMaT CORS	163364.573	69622.35	88.064						

Table 1 Relative Discrepancies between the Coordinates of CORS, the Temporary Occupied Reference Station, and the Conventional Method

Points Description	Discrepancies (CORSTOR)			Discrepancies (TORTM)			Discrepancies (CORSTM)		
	Δ E	ΔN	ΔZ	Δ E'	ΔN'	ΔZ'	Δ E''	ΔN''	ΔZ''
TSM CT1	0.016	-0.180	0.873	0.002	0.028	0.012	0.018	-0.152	0.885
SGW 303 4.03 A1	0.035	-0.143	0.849	0.051	0.002	0.073	0.086	-0.141	0.922
GCG WR 4 10.52	0.008	-0.001	0.731	0.026	0.062	0.046	0.018	-0.063	0.777
DMP 2007 10	0.016	-0.171	0.715	0.004	0.007	0.137	0.012	-0.164	0.852
SGW 22.62 4	0.002	-0.164	0.740	0.000	0.000	0.000	0.002	-0.164	0.740
TSM 89.1A	0.026	-0.161	0.847	0.029	0.059	0.093	0.055	-0.22	0.940
DMP 2007 12	0.012	-0.148	0.710	0.013	0.015	0.182	0.001	-0.133	0.892
TSM 89.9	0.303	-0.144	0.820	0.321	0.001	0.073	0.018	-0.143	0.893
DMP 2007 11	0.012	-0.160	0.859	0.072	0.388	0.105	0.084	0.228	0.964
SGW 303B1 4.03	0.004	-0.158	0.828	0.005	0.026	0.077	0.009	-0.132	0.905
GCG W 35.15E	0.005	-0.159	0.825	0.115	0.075	0.033	0.120	-0.084	0.858
UMaT CORS	0.016	-0.138	0.875				0.034	-0.147	0.903
AVERAGE	**0.038**	**-0.144**	**0.806**	**0.058**	**0.060**	**0.076**	**0.038**	**-0.110**	**0.878**
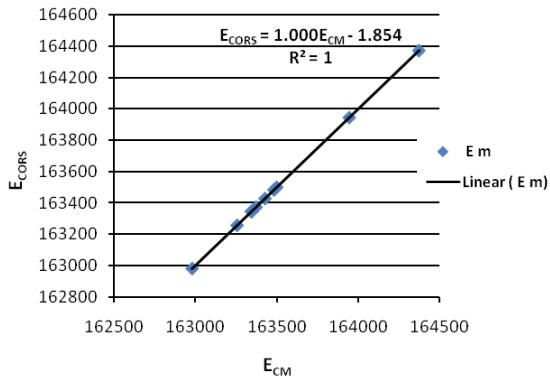
Fig. 2 Graph of the Eastings of points by the Conventional Method versus those of CORS
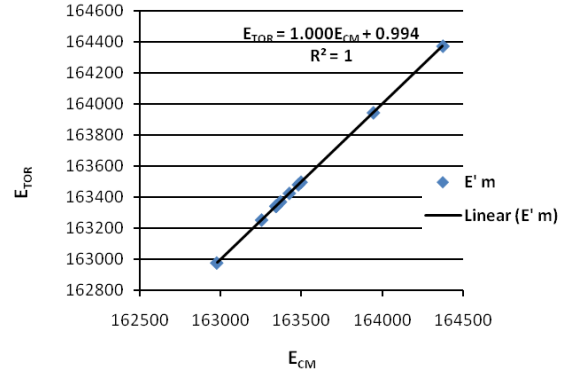
$E_{CORS} = 1.000E_{CM} - 1.854$
$R^2 = 1$

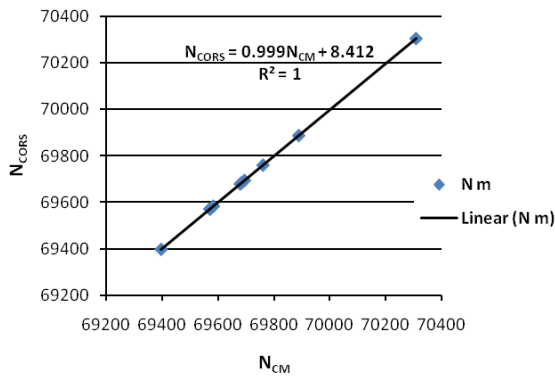**Fig. 5 Graph of the Eastings using the Conventional Method versus those of the Temporary Occupied Reference Station**

$E_{TOR} = 1.000E_{CM} + 0.994$
$R^2 = 1$

Fig. 3 Graph of the Northings of Points by the Conventional Method versus those of CORS

$N_{CORS} = 0.999N_{CM} + 8.412$
$R^2 = 1$
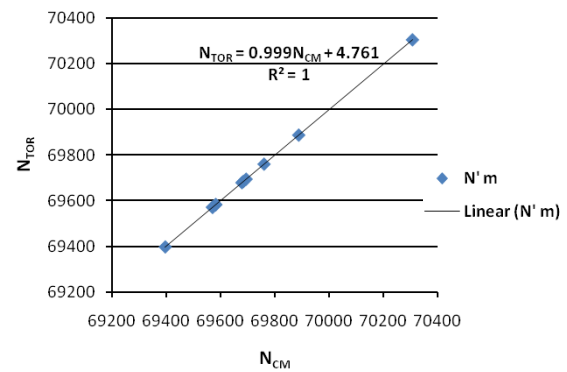
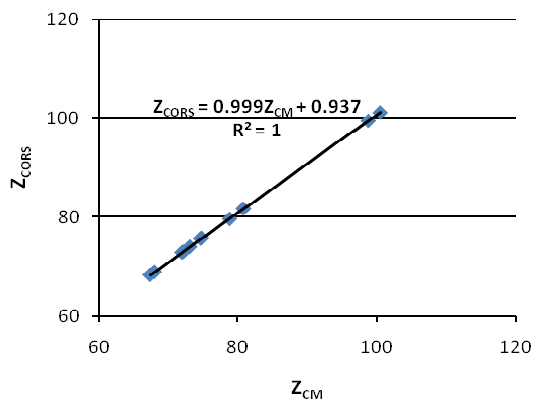**Fig. 6 Graph of the Northings using the Conventional Method versus those of the Temporary Occupied Reference Station**

$N_{TOR} = 0.999N_{CM} + 4.761$
$R^2 = 1$

Fig. 4 Graph of the Elevations of Points of Conventional Method versus those of CORS

$Z_{CORS} = 0.999Z_{CM} + 0.937$
$R^2 = 1$

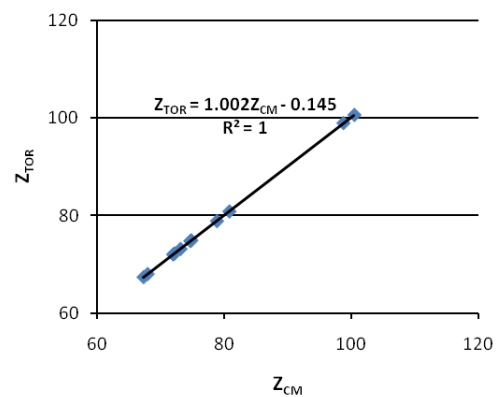**Fig. 7 Graph of the Elevations using the Conventional Method versus those of the Temporary Occupied Reference Station**

$Z_{TOR} = 1.002Z_{CM} - 0.145$
$R^2 = 1$

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The same pattern was observed in all the three sets of data collected and post-processed in the study. The variations in the easting coordinates in all three methods fell within the acceptable ranges of the accuracies of the instruments used. Errors in the planimetric positions might be due to an inherent error in the reference station. The apparently inherent error in the nothings of the reference station will inevitably affect the northings of the rover stations. This calls for further research. A systematic average discrepancy of 0.806 m in the coordinates of the heights may be attributed to the fact that the exact value for the geoidal ellipsoid separation has not been determined for the country, and was therefore assigned the value zero during the processing.

6 Conclusions

The three techniques employed in the determination of the coordinates of the selected points on the UMaT campus yielded acceptable results consistent with the discrepancies in the GPS post-processed coordinates of positions fixed with respect to the temporary reference station and those of the CORS.

The results of this work show that the correlation coefficients (r) are equal to +1 thus the scatter plots of the various coordinates of the control points are positively correlated and the regression equations for the eastings, northings and elevation were linear. Thus the CORS located at UMaT Campus can be effectively used in GPS surveys to yield accurate results which agree quite well with the local triangulation network in the region.

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